A NEW APPROACH TO THE P-WAVE DETECTION AND CLASSIFICATION BASED UPON APPLICATION OF WAVELET NEURAL NETWORK

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Abstract-**Paper presents a new approach to P wave classification problem which is based upon the application of a new recently develop and widely described tool such as Wavelet Neural Network. The novel idea of classification is based on creation of own non-standard wavelet exactly as a P wave morphology template and then calculation of wavelet transform being a first layer of classical multi-layer perceptron. The mentioned first layer works as a feature selector and extractor.**
***Keywords* - Wavelets, Neural Network, P-Wave Classification**

I. INTRODUCTION

The problem of automatic P wave detection and classification is not a new one in the computer assisted ECG processing and interpretation. However, current needs coming up from the physicians requirements apply more and more sophisticated methods leading to a significant increase of diagnosis process precision. Many authors published number of papers devoted to the P wave detection and classification problems presenting state of the art solutions such as application of Cross Wigner-Ville distribution [3], Gabor wavelets [1] or state-space model identification algorithm proposed by Juang and Pappa [5]. However, the P wave detection and further classification still remains not satisfyingly solved. The method presented in this paper combines signal processing facilities from two separated areas, namely wavelet transform analysis and neural network. Such a solution seems to be in perfect agreement with current tendency occurring among biomedical engineers i.e. to combine useful facilities from different signal processing fields, thus creating new tools for sorting out complicated problem, improving diagnostic precision and decreasing computation time. When the newly suggested method passes through the necessary performance tests, then it is easy, in the next step, to propose an implementation created with a help of DSP.

II. METHODOLOGY

Before description of the basic feature of new method it is necessary to become conscious what are the basic features and possible problems regarding P wave detection and classification. The most common problem is that very frequently it is hardly possible to observe P wave at all in the recorded ECG or in the extracted from the well known and widely accepted ECG signal databases, due to its small amplitude on one hand and a presence of noise on the other hand. To avoid that problem it is necessary to take into account the energetic aspect of the P wave detection.

The wavelet transform is known as extremely helpful tool which lead us to the improvement of that weakness. Assuming that detection of P wave is possible by application of the Gabor wavelets the next and most important step of the described method is a new classification process. Taking into account morphology of the P wave, the three different shapes were distinguished: monophasic, biphasic and M-shaped. The recognition of these three shapes is essential for the diagnosis of several atrial origin heart diseases. Considering the basic definition of the continuous wavelet transform eq.(1) it is easy to notice that under certain conditions this mathematical operation is nothing else than fully controllable correlation formula providing that wavelet ψ is one of the earlier created distinguished P wave template and the function f is an incoming P wave morphology for classification. Then if particular P wave is coming the result of wavelet transform operation will produce greater or more significant amplitude from that particular output where at the

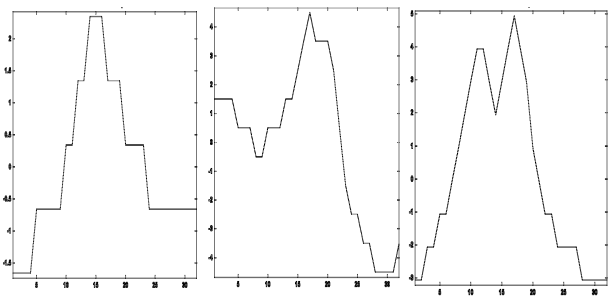

Fig..1. Three different types of P wave morphology: monophasic (a), biphasic (b), M-shaped (c).

$$W\psi\{f(t)\}(b,a) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

input is most similar P wave morphology. Considering the wavelet transform layer as a first layer of Neural Network it is possible to obtain in this way the preliminary classification results or a sort of P wave morphology feature extraction.

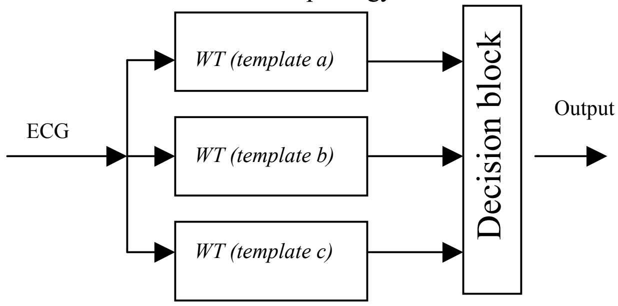

Fig..2. Block diagram of the idea of wavelet feature extraction.

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The wavelet transform calculated simultaneously in three channels, as in Fig.2 for the earlier dynamically extracted templates and current incoming shape of the particular P wave morphology causes that the neural network i.e. in this study a multi-layer perceptron is trained by processed signal, not by the original one. In other words the first layer of the wavelet neural network works as feature extractor or selector for further training providing that the special wavelets were created from the templates presented on Fig.1. Such an approach is very convenient as it allows to combine useful features coming from different method applied in the field of biomedical signals processing.

The decision block (see Fig.2.) can produce two possible feature extraction. First one concerns a set of wavelet coefficients and the second one describes the processed signal as a form of feature vector. Both maneuvers are convenient and acceptable for further neural network training (see Fig.3.).

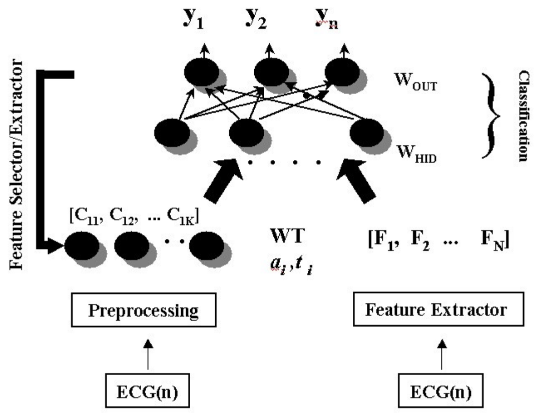

Fig.3. Wavelet Neural Network diagram for P-wave classification.

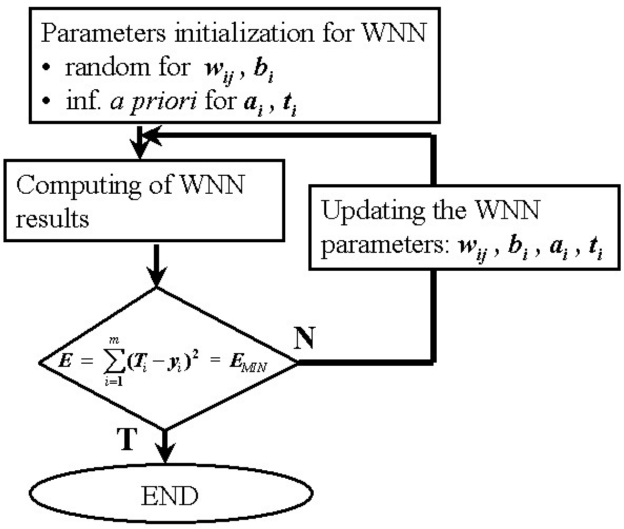

Fig.4. Block diagram illustrating WNN learning process

The diagram presented on Fig.3. illustrates mentioned above two possible results of application the wavelet transform as a first layer of typical neural network in the form of multi-layer perceptron. Fig.4. presents a block diagram of the learning process. Such a learning process requires parameters modification which are presented by the set of equations (2), where the transposed vector p^T designates an input vector for particular layer.

$$\Delta w_{i,j} = l_r * \frac{\partial E}{\partial w_{i,j}} * p^T$$

$$\Delta b_i = l_r * \frac{\partial E}{\partial b_i} \quad (2)$$

$$\Delta a_i = l_r * \frac{\partial E}{\partial a_i} * p^T$$

$$\Delta t_i = l_r * \frac{\partial E}{\partial t_i} * p^T$$

III. RESULTS

After the training procedure the necessary tests have been carried out on the real data taken from the commercial holter system. For classification purposes two different neural network structures have been tested. The first one consisting of one hidden layer and the second built up with the help of two hidden layers. There were four decision rules implemented to make decision concerning membership of

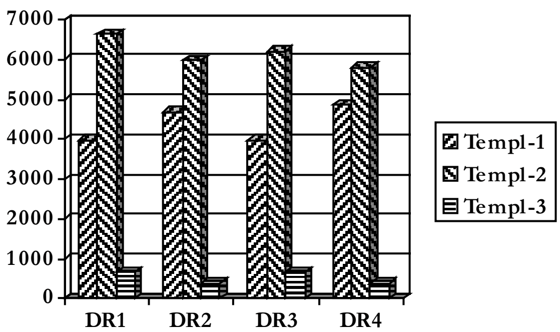

Fig.5. Results obtained through simulations with one hidden layer in Wavelet Neural Network structure

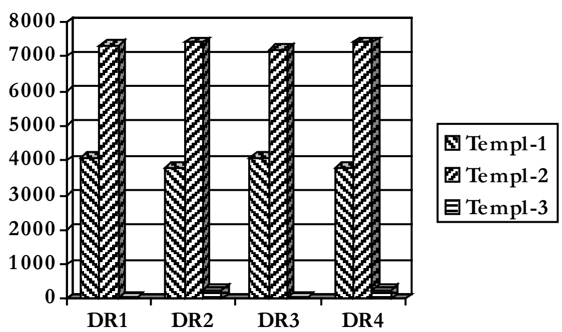

Fig.6. Results obtained through simulations with two hidden layer in Wavelet Neural Network structure

each particular currently incoming P-wave morphology

found in the 400 ms window back from the R peak in each QRS complex . The decision rules measured maximum in one (DR1) or three (DR2) channels of simulated data respectively and minimum of difference between simulated and real data in one (DR3) and in all three (DR4) channels respectively. Results of these measurements are presented on Fig.5 and Fig.6 for neural network with one and two hidden layers respectively.

TABLE 1

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	DR1	DR2	DR3	DR4	Commercial System
Neural network with one hidden layer					
Templ 1	3974	4685	3974	4855	4025
Templ 2	6633	5979	6213	5794	6550
Templ 3	665	387	666	392	665
Σ	11272	11051	10853	11041	11240
Neural network with two hidden layers					
Templ 1	4099	3803	4099	3799	4025
Templ 2	7331	7405	7193	7409	6550
Templ 3	52	265	52	265	665
Σ	11482	11473	11344	11873	11240

III. CONCLUSIONS

The presented method applies novel approach to the very old problem concerning detection and further classification of the P-wave in standard ECG. As it was already mentioned the solution of this problem is still far from the best one and on the other hand is extremely important taking into account all sorts of diseases of atrial origin. The method presented in this paper seem to be a novel first from methodology point of view as it applies wavelet neural network i.e. a combination of positive and useful features of wavelet transform and neural network and second both elaborated and tested algorithms can easily transferred from the Matlab environment to the implementation on available on the market DSP's.

It can be easily seen in the Table 1 that the worst result has been obtained for Template 2 and decision rule DR1 in case when neural network with two hidden layers has been applied. The specificity in this case is slightly more that 89%. All the other results obtained through simulations in Matlab environment were significantly better.

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